

Renewable Energy of Ukraine in Global Energy Transformations

Andrii Pecheniuk^{*1}, Ihor Garasymchuk², Pavlo Potapskyi³, Mykola Vusatyi⁴,
Viktor Dubik⁵, Vitalii Pukas⁶

¹Department of Finance, Banking, Insurance & Electronic Payment Systems, Podillia State University, st. Shevchenko, 13, Kamianets-Podilskyi, Ukraine 32300.

E-mail: anvaspe@meta.ua | ORCID: <https://orcid.org/0000-0002-8348-5044>

²Department of Electrical Engineering, Electromechanics and Electrotechnology, Podillia State University, st. Shevchenko, 13, Kamianets-Podilskyi, Ukraine 32300.

E-mail: igorgarasymchuk@gmail.com | ORCID: <https://orcid.org/0000-0002-4304-4447>

³Department of Electrical Engineering, Electromechanics and Electrotechnology, Podillia State University, st. Shevchenko, 13, Kamianets-Podilskyi, Ukraine 32300.

E-mail: p.v.potap@meta.ua | ORCID: <https://orcid.org/0000-0003-4792-8992>

⁴Department of Electrical Engineering, Electromechanics and Electrotechnology, Podillia State University, st. Shevchenko, 13, Kamianets-Podilskyi, Ukraine 32300.

E-mail: 0611142015vys@gmail.com | ORCID: <https://orcid.org/0000-0003-3070-9283>

⁵Department of Energy Saving Technologies and Energy Management, Podillia State University, st. Shevchenko, 13, Kamianets-Podilskyi, Ukraine 32300. E-mail: vmdubick@gmail.com | ORCID: <https://orcid.org/0000-0002-9743-1565>

⁶Department of the Tractors, Cars and Power Tools, Podillia State University, st. Shevchenko, 13, Kamianets-Podilskyi, Ukraine 32300. E-mail: pukasvital@gmail.com | ORCID: <https://orcid.org/0000-0002-0083-7359>

*Corresponding author

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Abstract

This article substantiates the need for the decarbonization of energy and the economy through the use of renewable energy sources. The advantages that the country achieves by stimulating the development of "green" energy are highlighted, in particular context of the achievement of significant economic, technological, ecological, and social effects. The global trends in the development of the renewable energy market are analyzed and evaluated using the main documents regulating the activity of "green" power generation. This article reveals the peculiarities of the functioning of the market of renewable energy sources in Ukraine, in particular. Specially noted are the difficult environmental situations in different regions of the country, the problems of reducing dependence on energy imports, and the destructive impact of the military aggression of the Russian Federation on the development of renewable energy in Ukraine. An assessment of energy consumption in Ukraine was conducted based on the renewable sources with the installed capacity of "green" energy facilities, and the dynamics of investment in the industry. The article has analyzed the factors that complicate the activities of participants in the market of renewable energy sources. The main trends in the development of "green" energy in the coming years are predicted, and a set of measures are proposed with the intention of improving the situation in the field of renewable energy.

Keywords

Renewable energy; Green energy; Energy market; Energy infrastructure; Energy dependence; Decarbonization

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Introduction

The development of an effective energy efficiency policy occupies a rather significant place in modern European and world politics. Energy efficiency has enormous potential to increase global productivity alongside reducing the waste and limiting the emissions. Growth in global energy demand is expected to come from low- and middle-income countries. Issues of energy efficiency are considered in the works of many scientists. For example, Fowlie and Meeks (2021) review the empirical evidence for both private and social benefits of improving energy efficiency and, in particular, underinvestment in the sector. Punt *et al.* (2022) examine the implications of the “institutional relatedness” of renewable resource cooperatives, arguing that they can use the organizational knowledge of cooperatives operating in other industries. Similarly, Brockway *et al.* (2019) explore the relationship between energy consumption and the GDP. The authors reiterated the rebound effect in the economy of the improvements in energy efficiency is larger than it is commonly believed. Their study revealed that many of the mechanisms that cause the rebound effect are not taken into account by comprehensive assessment and global energy models. Therefore, according to the authors' conclusions, global energy scenarios may underestimate the future growth rates of global energy demand.

Research results of Esen and Bayrak (2017) indicate that there is a positive and statistically significant relationship between energy consumption and economic growth in the long run. As a result, energy consumption contributes to economic growth as the country's dependence on imports decreases. In addition, the impact of energy consumption on economic growth also decreases as country's income level increases. Estache and Kaufmann (2011) consider energy efficiency taking an example from Belgium. They highlight in their publication an insufficient information related to the energy efficiency of buildings, but a high degree of decentralization of environmental policy in Belgium creating obstacles in the development of energy efficiency policy. Research by Fragkos (2022) focuses on improving the model of the global energy system. The author determined that increasing energy efficiency and increasing the circulation of materials can reduce energy consumption in all sectors, but, most importantly, in the industrial sector. Reduction of price of carbon needed is possible in order to meet the Paris targets¹ and the reliance on expensive, immature, and risky technologies, such as carbon capture and storage. Likewise, the research by Brockway *et al.* (2019) shows that 25% of UK's GDP growth since 1971 has been caused by improvements in energy efficiency. Strielkowski *et al.* (2020) highlighted the analysis of the determinants of economic efficiency and the assessment of the prerequisites for the energy security of smart cities. Until the end of the 20th century, the main production capacities of the countries of the world were characterized by the use, as a rule, of resource- and energy-intensive production technologies, which led to the deterioration of the environment. Further economic development requires a transition to a new business model and implementation of the basic principles of sustainable development.

One of the main reasons for climate change was the increase in the concentration of greenhouse gases in the Earth's atmosphere. To slow this process down, it is necessary to significantly reduce industrial emissions, in particular the CO₂. A significant share of global CO₂ emissions is produced by the energy sector. One of the most popular and effective ways of decarbonizing energy and the economy is the use of renewable energy sources (Economic Truth, 2021). Since the beginning of the 21st century, the process of implementing a new technological platform for the development of global energy has been gaining momentum in the world happening due to the need to respond to a number of economic, environmental, social, and technological challenges. One of the most important features of this process is a change in the structure of energy production and consumption balances due to an increase in the share of technologies based on renewable energy sources. Renewable energy is a sector of the world's energy that is developing very fast (Ryazanova, 2017).

¹ <https://unfccc.int/process-and-meetings/the-paris-agreement/katowice-climate-package>

In addition, modern world economy faces the urgent problem of minimizing adverse climate changes by transitioning to "green", cleaner energy (wind, solar, geothermal, sea tides, hydro- and bioenergy, energy from waste processing, hydrogen, etc.) (Borovsky, Yelagin and Polyakova, 2020). According to forecasts of Shen company experts, by 2040, 60% of the world's electricity will be obtained from renewable sources². Already, several countries, including Iceland and Costa Rica, fulfill 99% of their needs by "green" energy (Shen Facility Management, 2020). Moreover, traditional sources of energy are exhausted over time, and non-traditional ones (solar, wind, thermal and hydropower) become relevant, thanks to modern technical achievements, and are widely available (Akymenko and Kostyuchenko, 2020). The urgency of implementing the concept of a "green" economy in Ukraine is caused by the complex socio-economic situation, problems with the quality of the environment in some regions of the country, significant energy dependence on foreign markets, low energy efficiency of a number of industries, deterioration of the nation's health and the quality of life of the population (Borovsky, Yelagin and Polyakova, 2020). The purpose of this article is to develop proposals for improving the functioning mechanism of the renewable energy market in Ukraine and improving the industry's investment attractiveness.

Methodology

To assess the potential of renewable energy sources in the world, the results of research by scientists at Lappeenranta University of Technology (Finland) were used to forecast the negative impact on the environment at the current rates of production, technologies and level of consumption. The information from the specialists of the Organization for Economic Cooperation and Development (OECD) and the calculations done by the Carbon Tracker Initiative's analytical center were used to analyze the results of the Paris Climate Summit. Similarly, data from BloombergNEF³ were adopted to summarize the information about investing in the renewable energy sector. To know the capacity structure of the renewable energy industry in the world, the report of the International Renewable Energy Agency (IRENA)⁴ was analyzed.

While analysing the factors contributing to the development of the renewable energy industry in Ukraine, few expert assessment reports were used, including the reports of Yaroslav Demchenkov⁵ (Deputy Minister of Energy of Ukraine), Volodymyr Omelchenko⁶ (Director of Energy Programs of the Razumkov Center), and Yulia Usenko⁷ (Head of the All-Ukrainian Investment and Sustainable Development Agency). The results of 2014 research by the company Shen Facility Management Ukraine⁸, by independent news NV-Business⁹, and by a team of professional journalists of Ukraine were analyzed.

Calculations and graphical interpretation of the dynamics of energy consumption based on renewable sources, and the installed capacity of renewable energy facilities in Ukraine, were carried out using Microsoft Excel spreadsheets. At the same time, data published by the State Agency for Energy Efficiency and Energy Saving of Ukraine¹⁰ were used. The trend line method¹¹ was used to forecast the share of electricity consumption from renewable sources in Ukraine. Trend lines are a tool of technical analysis, which is a geometric representation of the average values of the analyzed indicators, obtained with the help

² <https://shen.ua/tendentsii-rynska-rozvytok-rynsku-alternatyvnyh-dzherel-energiyi-prognoz-i-perspektyvy/>

³ <https://about.bnef.com/>

⁴ <https://www.irena.org/>

⁵ <https://www.ukrinform.ua/rubric-presshall/3457272-masstabi-skodi-energosistemi-ukraini-zavdanoj-vijnou-ta-rozvitok-alternativnih-dzherel-energii.html>

⁶ <https://ecopolitic.com.ua/ua/news/ukraina-perevikonie-nvv2-chi-ie-privodi-dlya-optimizmu-rozpoiviv-ekspert-centru-razumkova-volodimir-omelchenko>

⁷ <https://www.epravda.com.ua/columns/2022/04/29/686428>

⁸ <https://shen.ua/en/services/facility-management/>

⁹ <https://english.nv.ua/business.html>

¹⁰ <https://saee.gov.ua/en>

¹¹ <https://www.ibm.com/docs/en/cognos-analytics/11.1.0?topic=methods-trend-linear-straight-line>

of a corresponding mathematical function. The choice of function for constructing a trend line is usually determined by the nature of the change in data over time.

Results and Discussions

Decarbonization of the energy sector through the development of renewable energy is a necessary condition for improving the environmental situation in cities and regions of Ukraine in the context of the international climate dialogue (Ryazanova, 2017). The global increase in energy prices leads to a decrease in the production and to an inhibition of socio-economic development in Ukraine. Therefore, reducing energy dependence through an effective energy saving program and the development of renewable energy in Ukraine needs an urgent solution (Dobryanska, Lagodienko and Torishnya, 2020). According to Demchenkov (2022), the development of "green" energy is important specially in context of Ukraine's aspirations to be the member of European Union. As a rule, alternative energy includes solar, wind, geothermal energy, biogas, biomass energy, hydropower, and secondary energy resources.

The findings of this research indicate that the potential of renewable energy sources is capable of providing sufficient and reliable electricity supply around the world by 2050. Such a prospect encourages investors to mobilize significant funds for the improvement of renewable energy technologies (NV-Business, 2022). Akymenko and Kostyuchenko (2020) claim that the development of renewable energy contributes to improving the trade balance, creating new jobs, solving social issues, reducing dependence on energy imports, ensuring the country's energy independence, increasing the competitiveness of products, and improving the conditions of foreign economic activity. The use of renewable energy significantly reduces the risks of man-made disasters, unlike traditional power generation. The dynamic development and effective functioning of alternative energy contribute to the achievement of the following effects:

- economic: resource conservation and reduction of energy intensity of production, development of economic potential, reduction of energy costs in all areas of business;
- technological: development and implementation of innovative technological solutions in the field of energy supply, renewal of energy-generating equipment, modernization of power plants and power networks, "greening" of energy infrastructure;
- environmental: reduction of anthropogenic and technogenic impact on the environment, significant reduction of hazardous industrial waste volumes, improvement of the environmental situation in general;
- social: ensuring access of the population to relatively cheap ecological energy sources of biological origin, implementation of a socially oriented model of energy consumption based on the principles of sustainable development, and creation of additional jobs (Khristenko and Gurska, 2021).

According to the forecasts of the Organization for Economic Cooperation and Development (OECD), at the current status of production, technologies, and consumption by 2050 compared to 2000, the world may lose from 61-72% of flora and fauna, and more than 7.5 million km² of natural areas will be irreversibly disturbed (Borovsky, Yelagin and Polyakova, 2020). Although the share of renewable sources in energy production continued to grow globally in 2020, CO₂ emissions could not be significantly reduced even in a view of the decline in economic activity. Therefore, as part of the concept of sustainable development in developed countries, programs in the fields of energy efficiency and energy saving are being implemented at the national, regional, and sectoral levels, one of the main components of which is the stimulation of the use of renewable energy sources (Gerasymchuk and Romanyuk, 2014).

The history of the development of renewable energy begins at the end of the 20th century, when the ability of renewable energy sources to compete with fossil fuels was quite doubtful. At that time, solar, wind,

geothermal types of energy, and biofuels were called "alternative energy"; they were considered as a narrow, unpromising, and expensive niche. However, during the first 10 years of the 21st century, interest in renewable energy technologies on the part of governments, investors and the public gradually began to increase (Zaharii and Kovalchuk, 2021). Back in 2009, the International Agency for Renewable Energy Sources (IARES) was founded with the headquarters in UAE, the purpose of which was to provide support for the use of renewable energy sources. The Agency has developed a "road map" to double the share of alternative energy sources in world consumption for the period 2010-2030. Ukraine, as a participant, has also undertaken to develop "green" energy. In 2015, at the 70th session of the UN General Assembly, the project "Transforming our world: an agenda for sustainable development until 2030" was developed by representatives of member countries. In the field of energy, the share of renewable energy sources in the global energy balance was expected to double. This issue was a key issue at the Paris Climate Summit, where the participating countries adopted a new global climate agreement. According to the provisions of this agreement, 191 participating countries agreed to keep the increase in the average global temperature within 20°C until 2100. According to the calculations of the Carbon Tracker Initiative think tank, in order to achieve the goals of the Paris Agreement, one coal-fired power unit should be closed every day in the world (Economic Truth, 2021).

Since 2015, the role of alternative energy sources in global energy has been increasing. Most of the world's countries are implementing energy efficient measures as part of their climate commitments. The use of a certain type of renewable energy sources for the production of electricity depends on the available natural resources, economic conditions and historical development of each region. The largest producers are China, the USA, Japan, India and Germany. Over the past 10 years, investments in renewable energy sources amounted to more than USD 300 billion (Makhnenko, 2021). In 2020, "green" energy production in the EU became taller than "fossil" fuel energy for the first time. This rapid growth was made possible due to the government programs supporting green power generation. In many countries, electricity produced on the basis of renewable sources has a privileged status; it enters the grid network and is received and consumed in the first place. For example, Spain earmarked USD 215 million in the public budget for renewable energy projects, and Portugal allocated Euro 10 million for subsidies to farmers who want to install solar power plants (NV-Business, 2022). According to BloombergNEF, in 2020, the world invested a record amount of funds in energy transition technologies - USD 501.5 billion, of which USD 303.5 billion in renewable energy (Economic Truth, 2021). By the end of 2021, 3,064 gigawatts (GW) of renewable generation capacity were operational worldwide, including 40% of hydropower plants (1,230 GW), 28% of solar power plants, and 27% of wind power plants. Statistically, solar energy and wind have grown many fold faster than hydropower over the years (Avenston, 2021). IARES notes that, in 2021, a historical record was set for the introduction of renewable energy capacities. The agency predicts that renewable energy will grow by more than 60% over the next 5 years (NV-Business, 2022). In the global markets where the share of renewable energy sources is significant, there is a decrease in average exchange prices for electricity.

According to the Law of Ukraine "On Alternative Energy Sources"¹² dated 20 February 2003, alternative energy is a field of energy that ensures the production of electric, thermal and mechanical energy from alternative energy sources, which are renewable energy sources i.e., solar, wind, geothermal energy, hydrothermal, aerothermal, wave and tidal energy, hydropower, biomass energy, gas from organic waste, gas from sewage treatment plants, biogas, and secondary energy resources. The secondary energy sources include blast furnace and coke gases, methane gas from degassing of coal deposits, conversion of waste energy in potential technological processes (Chumachenko, 2020). It is worth noting that national legislation distinguishes between "alternative" and "renewable" energy sources; alternative energy sources include not only environmentally friendly renewable sources, but also secondary energy resources. Renewable or inexhaustible energy resources are energy flows that are constantly or periodically operating in the

¹² <https://zakon.rada.gov.ua/laws/show/555-15#Text>

environment. Renewable energy sources include the energy of the sun, wind, seas and oceans, heat of the earth, biomass, small rivers and secondary resources that exist constantly or periodically appear in the environment.

The main document that defines the main strategic goals of Ukraine in energy and regulates the development of alternative energy is the Energy Strategy of Ukraine for the period until 2035 "Security, energy efficiency, competitiveness". This document should be considered as a basis for the development of alternative energy development programs at the state, regional, local levels (Poppel, 2018). According to the report of the PBL Netherlands Environmental Assessment Agency¹³, in 2018, 560 kg of CO₂ emissions accounted for USD 1,000 GDP in Ukraine. In Germany, this indicator is 200 kg, in Poland 300 kg, in EU countries 180 kg, in Saudi Arabia 360 kg, in the USA 290 kg (Economic Truth, 2021). Among the main factors that stimulate the use of renewable energy sources in Ukraine, it is worth highlighting the insufficient level of energy supply in some regions, the environmental consequences of energy production at thermal power plants, and the high potential of the types of "green energy". A number of Ukrainian economists believe that realizing the potential of renewable energy will improve the trade balance, create jobs, stimulate economic activity, and contribute to the renewal of outdated basic production assets in the energy sector (Dobryanska, Lagodienko and Torishnya, 2020). The development of "green energy" is an important prerequisite for reducing dependence on natural gas imports and diversifying sources of energy supply, which, in turn, will strengthen the country's energy security. Makhnenko (2021) segregates the positive factors of investing in the "green energy" of Ukraine: advantageous geographical and geopolitical location, favorable natural and climatic conditions, temporary exemption from taxation of value-added tax on transactions involving the importation into the customs of Ukraine of the main equipment for the construction of solar power plants, the availability of a sufficient number of land plots suitable for placing solar power plants and solar batteries, the availability of infrastructure for connecting solar power plants to the power system.

In general, the legislative framework of Ukraine provides favorable conditions for the development of renewable sources in the energy market and actually guarantees a return on investments. For example, the entire amount of electricity produced from alternative sources is purchased at a "green" tariff by the wholesale market. In addition, Ukraine has established one of the highest "green" tariffs in the world, which is tied to the current exchange rate of the Euro. If the technologies of Ukrainian origin are used at the power plant, an additional tariff surcharge of 10% is added, which in turn provides guarantees for the investor, creates new opportunities and reduces inflation risks (Khmelnyuk and Huk, 2021). However, new mechanisms for supporting "green" energy, such as "green" auctions and Net Metering, are still under development. However, despite these drawbacks, renewable energy sources are competitive and continue to grow. Analysis of energy consumption based on renewable sources in Ukraine over the last decade shows a decrease in the amount of energy consumed by hydroelectric power plants by 30.9% (from 941 to 650 thousand tons of oil equivalent - t.o.e.). At the same time, there is a 79.4 fold increase in wind and solar energy consumption (from 10 to 794 thousand t.o.e.) and a 2.7 fold increase in biofuel and waste energy (from 1,563 to 4,241 thousand t.o.e.) (Figure 1).

It should be noted that over the past 10 years, the share of electricity consumption from renewable sources in Ukraine has increased 4.1 times (from 2 to 8.1%) (Figure 2). According to this indicator, Ukraine ranks penultimate in Europe (8.1%), ahead of Luxembourg. But the largest share of consumption is in Iceland, Norway, Sweden and Finland (Word and Deed, 2021).

Date in table 1 shows that if the trends of the development of "green" energy are sustained, in 2025 the share of electricity consumption from renewable sources in Ukraine may reach 13.3%. According to the Statistical Service of the European Union, after several decades, Ukraine can potentially cover 74% of its needs with

¹³ <https://www.pbl.nl/en>

this technology (Shen Facility Management, 2020). According to the State Agency for Energy Efficiency and Energy Saving of Ukraine, the installed capacity of renewable energy facilities in Ukraine increased 9.5 times from 2014 to 2021¹⁴ (from 967 to 9225 MW) (Figure 3).

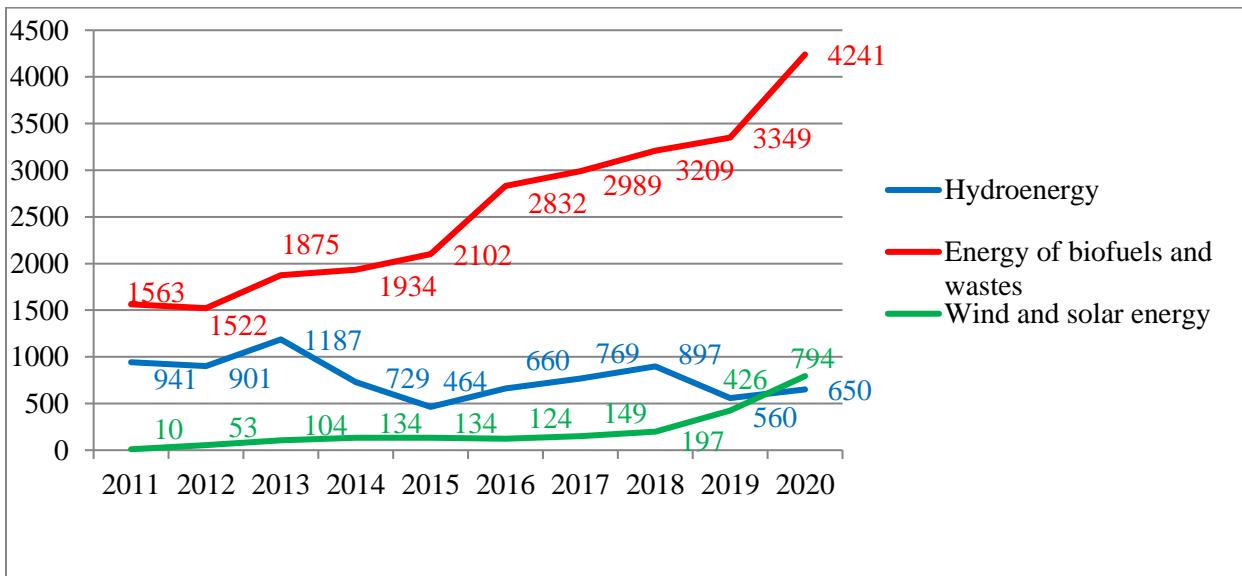


Figure 1. Energy consumption from renewable sources in Ukraine, thousand t.o.e.

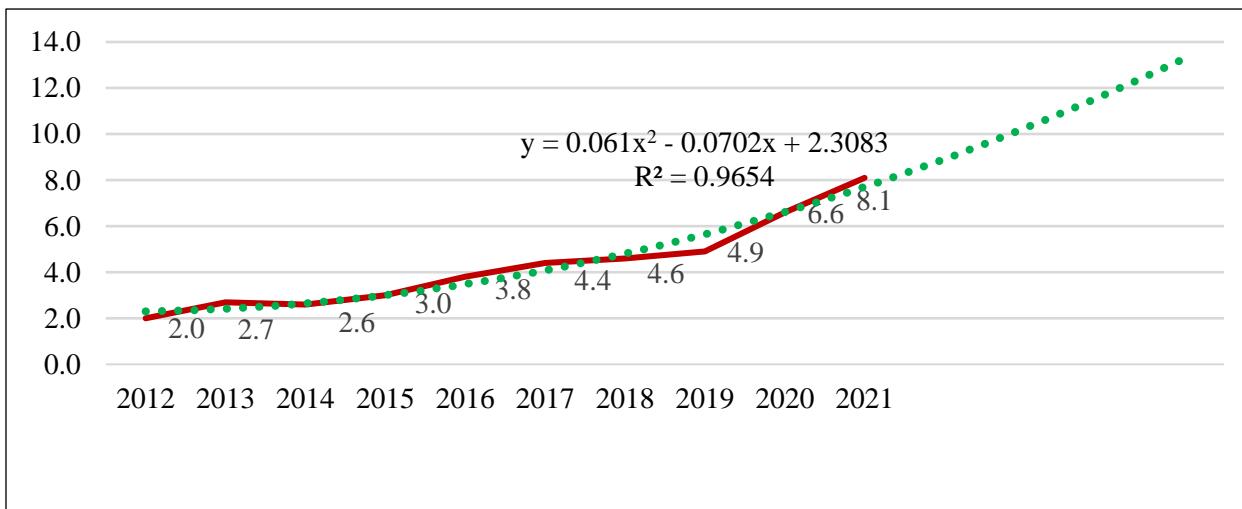


Figure 2. The share of energy supply from renewable sources in Ukraine, %

Table 1: Dynamics and forecast of the share of energy supply from renewable sources in Ukraine

Item	Unit	2016	2017	2018	2019	2020	2021	Forecast			
								2022	2023	2024	2025
The share of energy supply from renewable sources	%	3.8	4.4	4.6	4.9	6.6	8.1	8.9	10.2	11.7	13.3

¹⁴<https://interfax.com.ua/news/greendeal/791310.html>

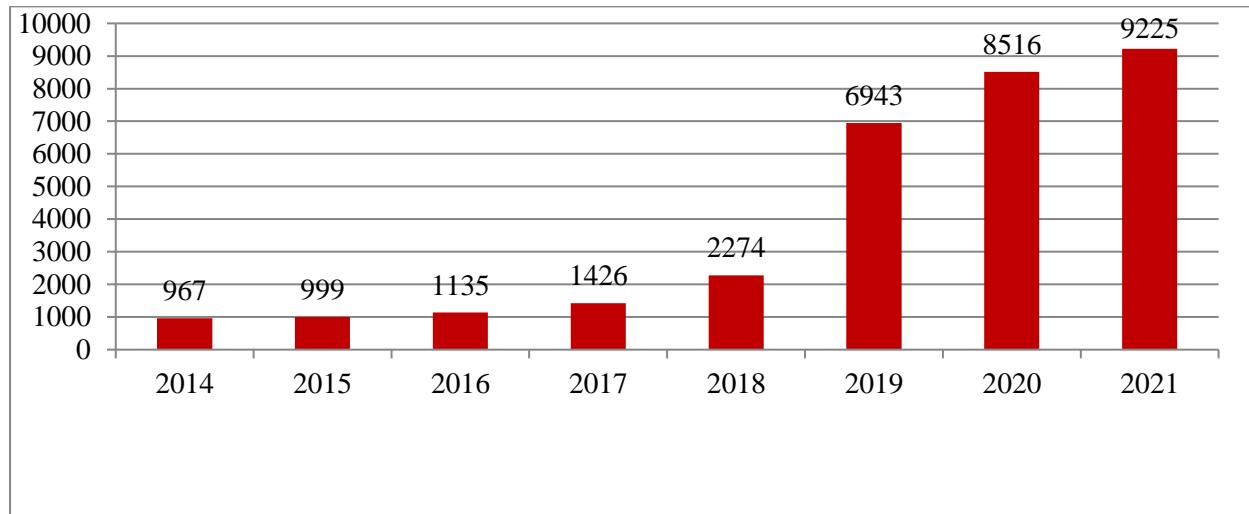


Figure 3. Installed capacity of renewable energy facilities in Ukraine, megawatts

Solar power plants have the largest capacity – as of the first half of 2021, they attributed to 6,351 megawatts. The capacity of wind stations was 1,593 megawatts. Household solar power plants have almost half the capacity – 933 MW. Biomass, small hydro and biogas power plants had a capacity of just over 100 megawatts in 2021 (Word and Deed, 2021). The dynamics of investing in renewable energy in Ukraine are unstable (Figure 4).

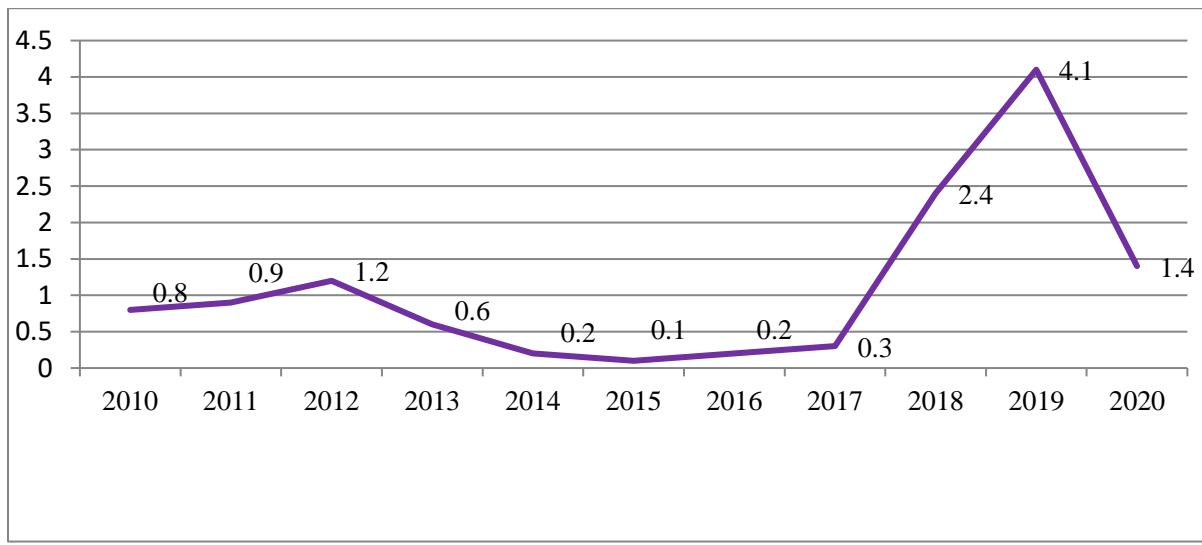


Figure 4. Investments in renewable energy sources in Ukraine, billion US dollars

A significant increase can be noted in investment volumes in 2018-2019 (from 0.3 to 4.1 billion USD) and a sharp decline of almost three times in 2020, which was caused by the government's refusal to fully pay the funds stipulated in the agreements to investors in "green" energy for generated energy. An analysis of the investment attractiveness of the renewable energy sector shows that most investments fall on the development of solar, wind, and hydropower, while energy using biomaterials and geothermal sources are less popular in Ukraine. This state is due to the fact that the energy of the sun, wind, and water are more

accessible and can be produced in many regions, but this cannot be said about other types of "green" energy sources.

Economically, renewable energy is competitive in Ukraine. However, the market is not developing as fast as it could. According to NV-Business experts, the main reasons for this are imperfect legislation, the lack of convenient credit programs, as well as the State's failure to fulfill its obligations to producers in the renewable energy sector. The development of "green" energy is significantly hindered by cross-subsidization - the artificial lowering of electricity prices for the population. Such a policy leads to the degradation of the electricity market and condemns it to the accumulation of domestic debts (NV-Business, 2022). Makhnenko (2021) reiterates opacity of the procedure for obtaining permits, the wear and tear of power grids, and the unstable situation in the country are among the main factors that complicate the development of renewable energy. Experts of the Shen Facility Management (2020) believe that the attraction of investments in the development of renewable sources in Ukraine is hindered by an imperfect legal framework, a weak judicial system, and investors' fear of raiding energy infrastructure facilities. Khristenko and Gurska (2021) indicated a high level of monopolization of electricity production and supply processes, an underdeveloped domestic renewable energy market, imperfect systems for stimulating the development of the industry, and relatively high capital intensity of power plants are among the factors limiting the development of the renewable energy industry.

It should be noted that the Russian Federation's military aggression against Ukraine, which began on 24 February 2022, dealt a significant blow to the prospects for the development of Ukrainian renewable energy. With the beginning of the full-scale invasion of Russia, the stable operation of the Ukrainian energy system was threatened, the energy infrastructure of renewable energy facilities was significantly damaged due to the actions of the Russian army. The main capacities of renewable energy (solar, wind generation) are located in the southern and southeastern regions of Ukraine, where active military operations are currently taking place: the invaders primarily attack transformer substations, and power lines, and personnel comes under fire. Up to 40% of these facilities have already been destroyed or damaged. The indicator for wind energy is critical: about 90% of this power generation is located in the territory where active hostilities are taking place, and the generation of solar power has decreased by 40% (Omelchenko, 2022). All producers of "green" energy operating in the Ukrainian market found themselves in a rather difficult situation. It is not only about threats of shelling of stations, but also about significant limitations of the state-guaranteed support mechanism for renewable energy. According to experts' estimates, assets worth more than USD 5.5 billion are currently in the war zone, and almost USD 4 billion in questionable investments in neighboring regions. There are already significant losses of renewable energy (Demchenkov, 2022). As a result of hostilities and systematic violations of agreements with investors, the renewable energy sector is on the verge of bankruptcy. At the end of August 2022, the National Energy Company "Ukrenergo" owed about USD 0.4 billion (14.5 billion hryvnias) to the producers of the industry under the "green" tariff. This threatens the actual shutdown of many facilities in the industry. Usenko (2022) believes that the state should preserve the industry and develop plans for its development after the war.

In addition to the direct hostilities, there is another problem for the industry: the solvent demand for electricity has significantly decreased. The population consumed 30-40% less energy, payments fell significantly - by 40-45% (Omelchenko, 2022). Thus, the situation in "green" energy and energy in general has significantly worsened. The Ukrainian authorities do not have the financial means to support the "green" generation in the current conditions. Funds that enter the state treasury are directed, first of all, to military, humanitarian, and social purposes. And they are still not enough. Legislation regarding the "green" tariff is not enforced by the government. The state actually takes the funds that the "green" power generation could receive today and distributes them to "Ukrenergo" and "Energoatom", because it believes that these companies are more important. It is not necessary to expect significant support from the authorities until the end of the war.

If the military aggression of the Russian Federation continues, then the renewable energy industry in Ukraine will be on the verge of bankruptcy. The only thing that can change the situation is the help of foreign partners. They are already trying to create a decarbonization fund. Denmark even invested in it. The purchase of these capacities by international funds and banks can save "green" power generation in the current conditions. After the end of the war, we can expect an increase in the investment attractiveness of Ukrainian renewable energy. In this case, the desire of a large number of investors to invest in the economy of Ukraine is predicted. The "green" generation is quite attractive all over the world. Currently, it accounts for 80% of all investments in energy. But the implementation of such a scenario requires an appropriate and effective economic policy of the government. First of all, the model of the functioning of the energy market needs to be improved: compliance with the state's obligations to investors, development, and implementation of a system of incentives for the development of the industry, overcoming corruption in the energy sector, independence of the judicial system from the influence of the executive power and representatives of big business.

Consulting and auditing company Deloitte (NV-Business, 2022) predicts that the main trends for renewable energy in the coming years will be:

- development of new generation technologies, in particular the use of artificial intelligence to optimize energy processes;
- introduction of new business models (in particular, business models for energy storage systems and expansion of "green" projects to new markets);
- infrastructure development for renewable energy projects;
- improvement of energy supply chains;
- implementation of circular economy principles (rational use of resources and recycling of secondary raw materials).

To implement strategic goals in the renewable energy sector of Ukraine, the following measures should be taken:

- implementation of a stable and predictable policy to stimulate the construction of solar and wind power plants;
- conducting international communication campaigns to encourage international strategic and financial investors to invest in Ukrainian "green" energy;
- ensuring the implementation of projects on the decentralization of energy supply at the local level (based on the use of renewable energy, "smart networks", increasing energy efficiency);
- commissioning of new units of hydroelectric power stations (subject to confirmation of environmental safety of projects);
- promoting the creation of an effective system for forecasting electricity generation;
- improvement of the mechanism for stimulating the production of energy equipment in Ukraine;
- increase in the use of biomass in electricity and heat generation;
- creation of conditions for the formation of a logistics support system and infrastructure for collecting biological raw materials and their further transportation;
- stimulation of electricity generation by low-power renewable energy installations.

At the same time, the Government of Ukraine should effectively use the entire range of incentives and mechanisms for investing in renewable energy: public-private partnerships, cooperatives, and energy communities, new mechanisms for the development of renewable energy sources, such as net energy consumption accounting and bilateral agreements on the purchase of electricity, which provide certainty and stability for both producers and long-term buyers of clean energy. To increase the level of transparency

in the energy market in Ukraine, there is an urgent need to hold "green" auctions, which will promote competition between investors and stimulate companies that offer the lowest prices for electricity.

The active spread of renewable energy technologies in the country will be facilitated by the new "green" industrial partnership between Ukraine and the EU, which will open up new opportunities for the whole of Europe. In the short term, this would help Ukraine recover from the war and improve the energy sector and economy in general (Krynytskyi, 2022). Adequate changes are also expected in the legislation on stimulating the production of electricity from renewable sources on a market basis, which will allow producers of "green" electricity to act as independent market participants and increase revenues. Legislative regulation is required to create a new participant in the market - an energy storage system operator, which will balance the operation of the energy system and increase the stability of the electricity supply for consumers. The implementation of an innovative breakthrough in the use of alternative energy sources in Ukraine is impossible without the involvement of significant external and internal investment resources, which are the key to the transition to an innovative model of the development of renewable energy enterprises.

Conclusions

In recent years, Ukraine has faced an acute problem of developing the renewable energy industry, which would help solve a number of economic, technological, environmental, and social problems. It should be noted that the installed capacity of renewable energy facilities in Ukraine from 2014 to 2021 increased by 9.5 times, and over the last decade, the share of electricity consumption from renewable sources in Ukraine has increased by 4.1 times (provided that "green" energy in 2025 reached 13.3%). The instability of the investment process in the field of renewable energy is evidenced by the rapid growth of investment volumes in 2018-2019 (from 0.3 to 4.1 billion USD) and a sharp decline of almost 3 times in 2020. The full-scale military invasion of the Russian Federation, which began on 24 February 2022, dealt a fairly significant blow to the prospects for the development of Ukrainian's renewable energy - at stake are assets worth more than USD5.5 billion in the war zone and almost another USD 4 billion in investments in nearby regions. If the military aggression of the Russian Federation does not stop within a year, the renewable energy industry in Ukraine will be on the verge of bankruptcy. To ensure the effectiveness of the development of renewable energy sources in Ukraine, there is an urgent need to develop and implement an appropriate model of the functioning of the energy market, which would provide for compliance with the State's obligations to investors, the implementation of an effective system of incentives for the development of "green" energy, overcoming corruption in the energy sector, the independence of the judiciary systems from the influence of the executive power and representatives of big business, and implementation of a set of measures to encourage investment in Ukrainian renewable energy by international strategic and financial investors.

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Authors' Declarations and Essential Ethical Compliances

Authors' Contributions (in accordance with ICMJE criteria for authorship)

Contribution	Author 1	Author 2	Author 3	Author 4	Author 5	Author 6
Conceived and designed the research or analysis	Yes	Yes	No	No	No	No
Collected the data	Yes	No	Yes	No	No	No
Contributed to data analysis & interpretation	Yes	Yes	No	No	Yes	Yes
Wrote the article/paper	Yes	No	Yes	Yes	Yes	No
Critical revision of the article/paper	No	Yes	Yes	Yes	No	Yes
Editing of the article/paper	No	Yes	No	Yes	Yes	Yes
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